Tools to Compare Diving-Animal Kinematics with Acoustic Behavior and Exposure

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LONG-TERM GOALS

Intense international concern has arisen over the potential effects of anthropogenic sound on protected marine wildlife. To study this issue presents a challenge, however, because marine animals in captivity form a limited sample set that cannot always be extrapolated to wild populations, while those in the wild spend the majority of their time submerged and out of sight of researchers. Thus instrumentation to monitor the behavior and sound exposure of wild, free-ranging marine animals is essential.

Broadband acoustic recording tags offer a promising avenue for studying the relationship between behavior and sound exposure for free-ranging animals. Since 1995, when the first combined broadband-acoustic and behavior recorders were deployed with northern elephant seals (Burgess et al., 1998) such tags – predominantly the DTAG (Johnson and Tyack, 2003) and the Bioacoustic Probe (Burgess, 2000; Figure 1) – have seen extensive use in the study of baleen whales, sperm whales, and seals (e.g., Insley et al., 2007; Miller et al., 2004; Oleson et al., 2007). These studies have generated a dramatic quantity of acoustic, depth, and orientation data, and as combined acoustic/behavior tags become increasingly available the amount of data will continue to grow. This rapid expansion of data will not, however, support the commensurate expansion of study and understanding unless the wider research community is equipped to process and interpret those data effectively.

This program focuses on the collaborative improvement of two tools for acquiring and interpreting broadband acoustic and behavioral data: the “Acousonde™” broadband acoustic-and-behavior recorder (the next generation of the Bioacoustic Probe) and the “TrackPlot” kinematic-analysis software. Under this effort, Greeneridge Sciences (the Acousonde) and the University of New Hampshire (TrackPlot) are improving their respective tools in concert to maximize the data acquisition and interpretation capabilities of the wider bioacoustic research community. The three fundamental principles guiding development of both tools towards this transition are ease of use, flexible design, and broad availability.

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Figure 1. Photograph of the previous generation of the Acousonde™ (the Bioacoustic Probe) attached with suction cups to the back of a humpback whale (John Calambokidis, Cascadia Research).

OBJECTIVES

As the developer of the Acousonde, Greeneridge Sciences' objectives in its collaboration with the University of New Hampshire are: (1) to guide improvement of TrackPlot for maximum compatibility with the Acousonde; (2) to refine the Acousonde's data calibration and storage of metadata to support TrackPlot most effectively; and (3) to revise the Acousonde hardware to remedy any shortcomings brought to light by TrackPlot applications using Acousonde data.

APPROACH

The principal investigator will collaborate with Dr. Colin Ware of the University of New Hampshire to ensure that the Acousonde hardware and software provide all necessary data and metadata to maximize TrackPlot's accuracy and ease of use. The collaboration will also evaluate the precision and accuracy of the Acousonde's orientation and heading sensors, and document the methodology of acquiring and analyzing kinematic data from initial tagging to final interpretation.

To evaluate the Acousonde and TrackPlot under realistic conditions and to accelerate transition to the field-biology community, the investigators will test the tools with separately-supported biology partners. They will train those partners in the use of the tools, adapt the tools to partners' needs, and assist with initial data interpretation. Potential partners who have expressed interest in helping to field-test the Acousonde and evaluate TrackPlot include Dr. Whitlow Au of the Hawaii Institute of Marine Biology and Dr. Erin Oleson of the National Marine Fisheries Service.

With the Acousonde's behavioral sensors and software tested, the project will change focus to mechanical and attachment objectives specific to optimizing cetacean applications. The tag electronics will be reconfigured for casting in a unified suction-cup-and-electronics package together with a release mechanism, a housing for a VHF retrieval beacon, and sufficient buoyancy to assure flotation in the correct attitude for efficient VHF transmission.

WORK COMPLETED

The fifteen months since project inception on 18 June 2009 saw the following milestones: (1) the North-East-Down (NED) compass/accelerometer convention was chosen as the reference frame for the kinematic sensors in collaboration with Dr. Ware; (2) a completed Acousonde was delivered to the permanent custody of Dr. Ware for evaluation and continuing improvement of TrackPlot; (3) Dr. Ware supplied feedback on compass calibration for incorporation in a future operating software release; (4) we provided technical support for deployment of an Acousonde on a blue whale off of Los Angeles by Dr. John Hildebrand (Scripps Institution of Oceanography) and Mr. John Calambokidis (Cascadia Research); and (5) the Acousonde electronics have been reconfigured to fit in a unified suction-cup-and-electronics package (we hope to produce the first unified Acousonde tags in October 2010).

RESULTS

Many surprises hampered our progress, chiefly with development of the Acousonde itself. As the current program depended on prior completion of all Acousonde functionality, development setbacks profoundly affected our schedule. In particular, a vendor fabricated 20 new Acousonde electronics boards, all of which were faulty and yet passed the vendor's checks. Naturally, after the boards were assembled, none worked. By the time troubleshooting had isolated the problem and replacement boards were completed, three months had been lost.

Other major obstacles that impeded progress on the current program included filesystem write inefficiencies with unacceptably high power draws, compatibility with Microsoft Windows, and several severe operating-system reliability issues. These unexpected obstacles made it difficult to proceed with the current program until late in the summer of 2010.

Once the Acousonde supported all necessary functionality, a unit was delivered to the permanent custody of Dr. Ware. He conducted a preliminary evaluation and determined that, while the design provided adequate kinematic resolution (acceleration and compass), the compass required additional calibration capability to be useful. We plan to add this capability in October 2010.

The successful deployment of an Acousonde on a blue whale by Dr. Hildebrand and Mr. Calambokidis, obtaining 9 hours of broadband acoustic data and 15 hours of dive and kinematic data, demonstrated that the design has reached sufficient maturity for application (Figure 2). Much additional work remains under the present effort to improve the calibration and usability of the kinematic sensor data in concert with Dr. Ware, but all major development hurdles have been crossed.

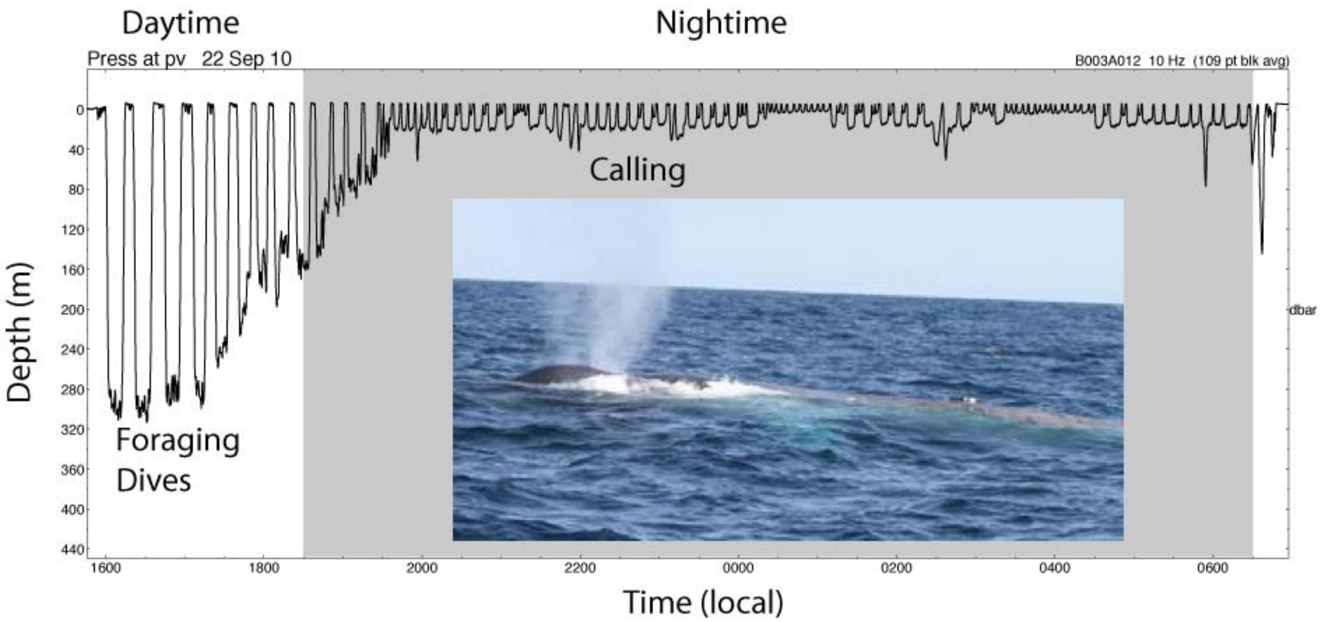

Figure 2. The first dive record obtained by the Acousonde. The record shows a transition from daytime foraging to nighttime calling behavior by the tagged blue whale (inset photograph). (John Hildebrand, Scripps Institution of Oceanography, and John Calambokidis, Cascadia Research)

IMPACT/APPLICATIONS

Acoustic recording tags measure sounds that a tagged animal makes or to which it is exposed, and monitor potentially associated changes in the animal's behavior. This quantitative knowledge of stimulus and response is fundamental to our understanding of protected species' acoustic sensitivity. In addition, for calling animals, behavioral data helps place a subject's calling activity in context, providing a better interpretive foundation for other studies that rely on acoustics alone.

While prior work has focused on improvements to the acoustic capabilities of the Acousonde, the present effort concentrates on improving the acquisition and interpretation of behavioral kinematic data. The effort will provide the wider bioacoustic research community with access to high-quality kinematic visualization of the behavior of tagged subjects.

The Acousonde is finding increasing utility in non-biological applications. As detailed below under transitions, such applications include vessel signatures, tactical oceanography, underwater gliders, and marine geophysics. Improvements to kinematic sensing and analysis under the present effort may increase the recorders' utility in these fields as well as in underwater or space robotics.

TRANSITIONS

The Acousonde and its previous generation, the Bioacoustic Probe, have been widely applied in acoustic research. Nineteen Acousondes and 43 Bioacoustic Probes have been built; 16 different research groups have applied them. Under Dr. John Hildebrand of the Scripps Institution of

Oceanography and Mr. John Calambokidis of Cascadia Research, B-Probes have been attached to blue whales (Oleson et al., 2007), fin whales (Goldbogen et al., 2006), and humpback whales; under Calambokidis and Dr. Aaron Thode of Scripps and, independently, Dr. Bruce Mate of Oregon State University, to sperm whales; under Dr. Whitlow Au of the Hawaii Institute of Marine Biology (HIMB), to humpback whales; under Dr. Stephen Insley, then at the University of California at Santa Cruz, to northern fur seals (Figure 3; Insley et al., 2007); and under Dr. Chip Deutsch of the Florida Fish and Wildlife Research Institute to manatees. Dr. Carl Meyer of HIMB temporarily sutured one B-Probe into a blacktip reef shark (Meyer et al., 2007). Most of these investigators will benefit from the improved kinematic analysis tools to be introduced under the current program.

Bioacoustic Probes have found applications beyond attachment to wildlife. Dr. Thode used them as independent elements comprising a portable acoustic array (Thode et al., 2006) and as convenient self-contained tilt-meters for conventional acoustic arrays; Thode and Dr. Gerald D'Spain of Scripps used them as acoustic and attitude sensors during prototype trials of the Liberdade X-Ray underwater glider (D'Spain et al., 2005); and Dr. Jim Miller of the University of Rhode Island obtained a B-Probe for use inside an autonomous underwater vehicle. Bioacoustic Probes have been employed as simple seafloor recorders in several studies, including a behavioral study of beluga-whale habitat usage (Burgess et al., 2005), a geoacoustic study of sediment properties (Tang, 2005), and geophysical studies of bubble seeps (Leifer and Tang, 2006) and geothermal vents (Chadwick et al., 2008).

More recently, we have collaborated with a shipbuilding contractor for the operational Navy to customize the Acousonde for noise assessment. This transition directly benefits fleet modernization. We have also provided the Acousonde to the Naval Postgraduate School for officer training in tactical oceanography, to the Monterey Bay Aquarium Research Institute for geophysical research (Henthorn et al., 2009), and to BP for studies of acoustic emissions from an offshore drilling island.

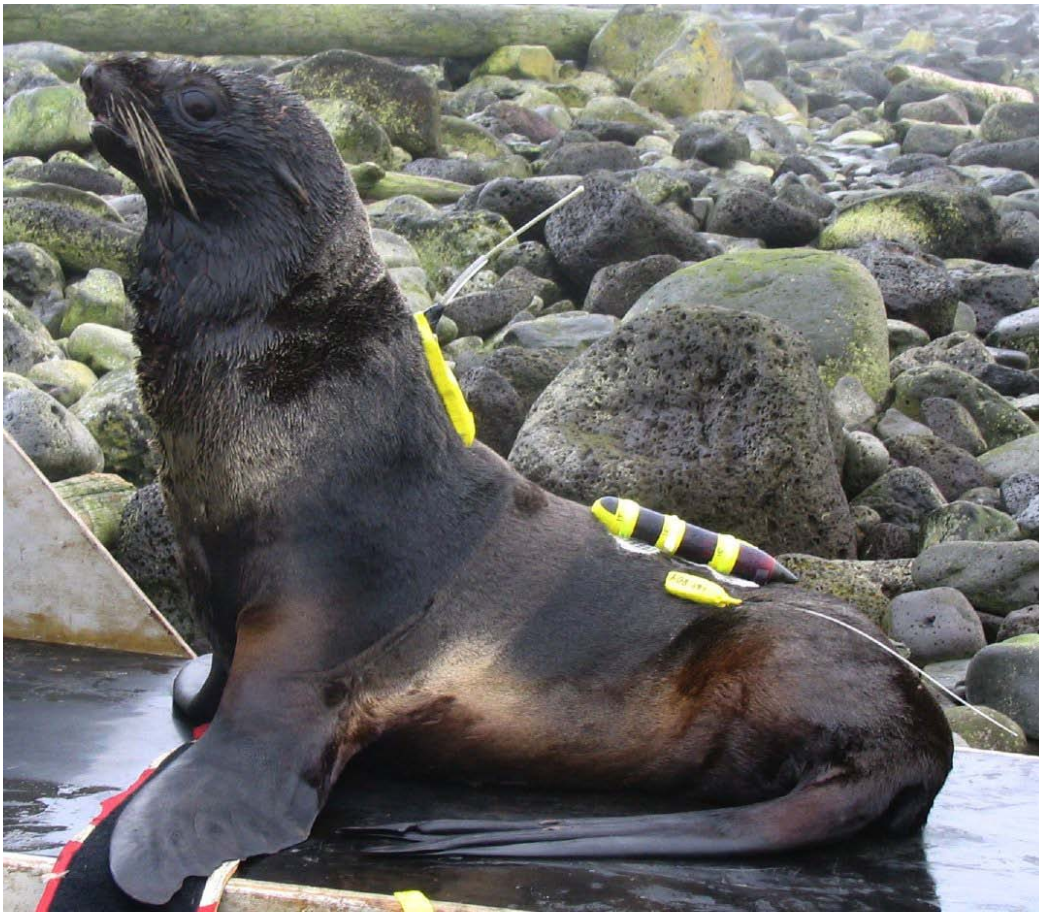

Figure 3. Photograph of a northern fur seal at the Pribilof Islands, Alaska, fitted with the previous generation of the Acousonde (the Bioacoustic Probe). Also fitted to the subject are a satellite location transmitter and a VHF retrieval beacon (Stephen Insley; Insley et al., 2007).

RELATED PROJECTS

The present work is a collaborative effort with Dr. Colin Ware of the University of New Hampshire, the creator of TrackPlot, separately supported under ONR Award number N00014-09-1-0601.

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